

## UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle)  Theory of Fuzziness and its Applications to Information Processing and Decision- Making		5. TYPE OF REPORT & PERIOD COVERED
7. AUTHOR(s)  L. A. Zadeh		6. PERFORMING ORG. REPORT NUMBER  DAAG29-76-G-0107
9. PERFORMING ORGANIZATION NAME AND ADDRESS  Electronics Research Laboratory University of California Berkeley, California 94720		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS  U. S. Army Research Office Post Office Box 1211 Research Triangle Park, N.C. 27709		12. REPORT DATE
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		13. NUMBER OF PAGES
		15. SECURITY CLASS. (of this report)  UNCLASSIFIED
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE
16. DISTRIBUTION STATEMENT (of this Report)  Approved for public release; distribution unlimited		
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)  NA		
18. SUPPLEMENTARY NOTES		
19. KEY WORDS (Continue on reverse side if necessary and identify by block number)  knowledge representation, decision-making		
20. ABSTRACT (Continue on reverse side if necessary and identify by block number)  Investigation of the application of production systems to the representation of knowledge and problem-solving.		

ADA064598

Mr. Rosell

ARO-12596.5-EL

THEORY OF FUZZINESS AND ITS APPLICATIONS  
TO INFORMATION PROCESSING AND DECISION-MAKING

FINAL REPORT

L. A. ZADEH

1 OCTOBER 1976

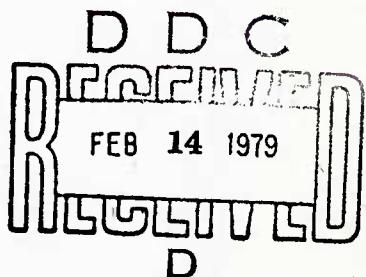
U. S. ARMY RESEARCH OFFICE

DAAG29-76-G-0107

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This research concerns itself with the investigation of design goals of various approaches used in Artificial Intelligence (AI) programs in order to solve problems in various domains of knowledge. Research problems that were investigated in these AI problem-solving systems are 1) the representation of knowledge, 2) the complexity of a system's control structure, and 3) the error processing capabilities of a system.

Other issues of a system-design nature that are of interest in this paper include 1) system extendability, 2) expressability, 3) modularity, 4) readability, 5) explanability of behavior, and 6) domain appropriateness for the solution paradigm.

System extendability concerns itself with adding knowledge to a system in increments. Such a feature is necessary since large-scale systems must show competence on a subset of the domain knowledge. The knowledge can change over a period of time (as in medicine) and the system must allow adaptation to this new knowledge.

The expressability of a system depends upon the format can be either fixed (e.g., a conditional clause) or allow the knowledge encoder the full power of programming language for representation.

Modularity deals with the separation of a program into isolatable functional units. A highly modular system would allow changing a functional unit without necessitating changes to other units within the system.

Readability system concerns itself with 1) the ability of humans to understand a system's structuring of knowledge, and 2) the ability of a system to read portions of itself. The latter capability is necessary if the system is to do consistency checks of the knowledge encoded in the system.

Two extreme solution paradigms involve 1) procedural encoding of domain knowledge and 2) data-driven production-rule encoding. The structures of the various existing procedural systems actually range from a pure-procedural encoding of knowledge to a procedural implementation of production systems.

An advantage of production systems (i.e. collections of production rules plan data base) is their extendability. Since production rules are completely independent (they communicate only indirectly through the data base) the modification, addition, or deletion of any rule is not seen by any of the other rules. This modularity and the fixed format of rule representation (e.g. if hypotheses thru conclusions) aid machine readability. The fixed format requires a number of rules in order to represent control structures of more complexity than conditional statements. The basic system control structure is to 1) select a rule and 2) execute that rule. A consequence is that at the beginning of any cycle potentially any rule can be executed depending only on the data base's current contents. The simple rule format allows easy human readability of individual rules but the behavior (on flow of control) of a system is normally very obscure. Production systems are most appropriate for domains where the knowledge is a collection of independent facts which are encodable as rules.

The various procedural systems involve problem-solving domains where there is interaction (e.g. competition or communication) between pieces of knowledge. In these systems the knowledge is encoded in procedures. Use of a piece of knowledge is equivalent to executing the associated procedure. Along with the increased expressability inherent in a procedure realizable control structures of immense complexity are

possible. Here the unit of modularity is the procedure: all relevant piece of knowledge are combined into a single procedure. This feature allows for easy readability of procedures by humans; but currently allows only limited machine readability of procedures. As such, the explanability of system behavior is dependent on the systems; complexity of control flow and possible parallel executing of procedures. Only those procedural systems that use pattern-directed invocation of procedures enjoy extendability; otherwise, reprogramming is necessary.

Both approaches to system design (production systems on procedures) have equivalent computational power. Their appropriateness in future systems will be dependent upon the desired features of a system's design; Hybrid system's are beginning to appear.

#### Personnel

Mr. Ralph Sobek has been advanced to Candidacy. Ph.D. expected in 1977.

#### Publication

Technical report is in preparation.